# GNSS Observations of Ionospheric Scintillations Due to Rocket Launches

**Daniel Koshy [koshyd@my.erau.edu], Jaclyn Adams, Skye Colonna, and Chintan Thakrar**
**Student Research Symposium 2020**
***Space Physics Research Lab - Department of Physical Sciences***

## Objectives

- Study and identify rockets as possible sources of disturbance in the ionosphere by analyzing the June 25, 2019 Falcon Heavy rocket launch case in Cape Canaveral, FL
- Utilize the Global Navigation Satellite Systems (GNSS) constellation to pinpoint these effects
- Study atmospheric effect in various rocket launches and apply the knowledge in the June 25th instance
- Expand current algorithm methods at the Space Physics Research Lab used to identify other phenomenon and build a team to work on this new initiative

## Introduction

### The Ionosphere & GNSS

- The ionosphere is a layer in Earth's upper atmosphere that is located approximately 80-1000 km above the Earth's surface
- This layer contains ions and free electrons that are known to cause drastic phase and power changes in signals known as ionospheric scintillations
- The GNSS network is composed of satellites that provide signal data at various altitudes
- SPRL has been utilizing this data as it has had provided reliable insight in past projects

### Why Rockets?

- Large enough rocket launches can stimulate notable changes in the ionosphere through a culmination of aftershock propagation waves, causing irregularities that threaten GPS signal reception
- These changes due to rockets are *rarely* noticed, and to the best of our knowledge, this is the first time this concept is being studied up close

*Figure 1: The Falcon Heavy Rocket has enough power from exhaust to elicit changes to ionospheric structures*

## Methodology and Current Results

### Data Collection

- Before any data is parsed or visually analyzed, the team utilizes a spreadsheet to organize dates in UTC (Universal Time Coordinated) and EST (Eastern Standard Time) of potential days rockets will be launched
- Novatel software is used by GPS receivers to pick up low and high-rate binary data from GNSS during specified launch times
- EISA (Embry-Riddle Ionospheric Scintillation Algorithm) is used to gather this data, which is then parsed and graphed into CSV files through a series of code using GPS data

*Figure 2: One of SPRL's GPS-703-GGG antennas on top of the COAS Building at ERAU*

### Results of 06/25/2019 Falcon Heavy Rocket Launch Case

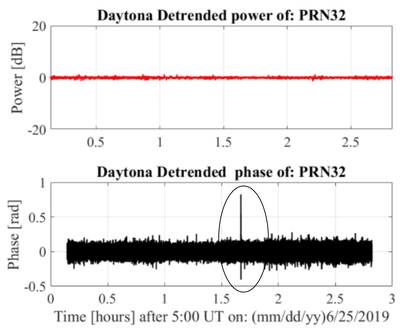


*Figure 3: This graph separates the changes in power and phase recorded by PRN32 on June 25, 2019. There is a notable change in phase of the signal*

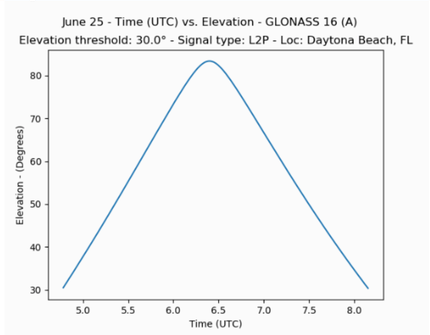


*Figure 4: The peak in phase at 6:30 UTC is believed to be an irregularity due to the rocket launch. Elevation is at about 75 degrees above horizontal axis.*

### Area of Focus on Trajectory & Total Electron Content (TEC) Results

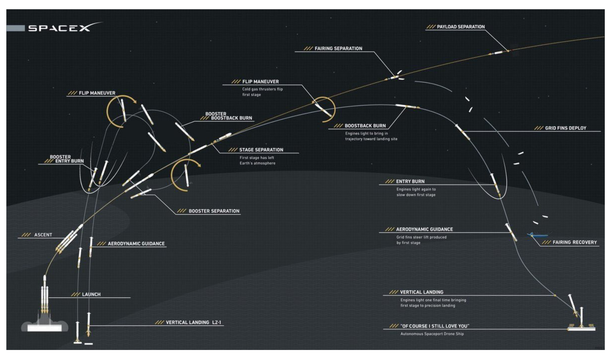


*Figure 5a*

*Figure 5b*

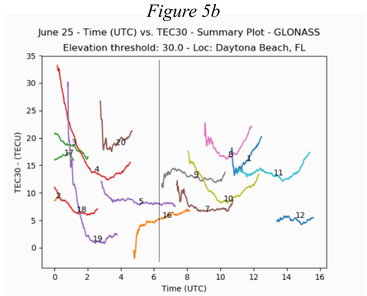


*Figure 5a & 5b: Figure 5a demonstrates the TEC activity shortly after the time of the launch (~6 UTC). Figure 5b demonstrates the path of Falcon Heavy. Our group focuses on the points between ascent and stage separation.*

## Conclusions

- In the June 25, 2019 instance we see that shortly after 5:00 UT there is a phase scintillation of approximately 1 radian demonstrating the ability of a rocket to cause fluctuation
- We see through Figure 5b that after 6 UTC, at the time of the launch there is not much TEC activity, which causes us to believe that the launch did not affect TEC as much as believed
- Figure 4 demonstrates that the signal we received was not a multipath, or alternative signal, due to its high angle.
- We can believe that due to the obvious scintillation in the signal, there is influence from acoustic waves

## Future Developments

- Facilitate recording of more rocket launches that could provide potential instances of disturbance.
- Make sure flow between Excel, parsing, and graph creation is user-friendly for future researchers
- Use GEMINI or SIGMA methods to model acoustic gravity waves
- Incorporate a triangular network array of receivers to gather more diverse sets of data
- Expand 2021 team and train future members

## Acknowledgements

- We would like to express our sincere gratitude to the following individuals:
  - Dr. Kshitija Deshpande for providing the inspiration, guidance, and advice throughout the development of this up-and-coming project
  - Shantanab Debchoudury for providing knowledge and insight into rocket launches
  - Marie Bals photography, 30th Space Wing Public Affairs, and NASA and SpaceX public data repositories